HIGH RESOLUTION BOTTOM CHARACTERIZATION

4 MAY 1993

D. MIKLOVIC

CONTRACT NO.: MDA972-91-C-0063

ARS-235-021-B

Areté Associates
P.O. BOX 8050, LA JOLLA, CALIFORNIA 92038

ADVANCED PROCESSING FOR BOTTOM CHARACTERIZATION

Goal: Identify and quantify dominant scattering mechanisms in bottom limited environments.

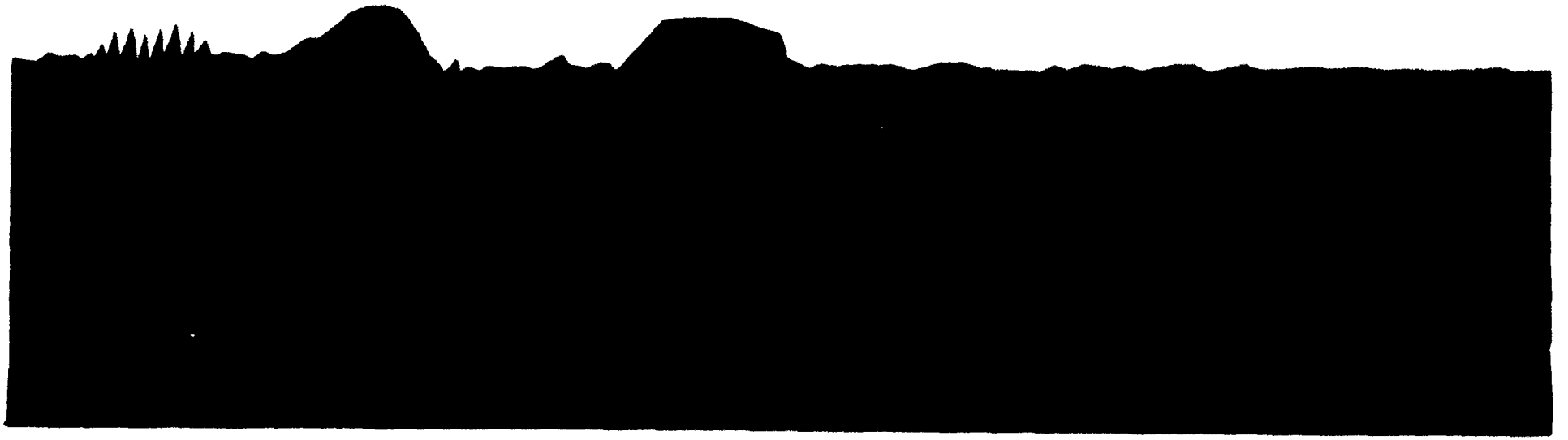
Approach

- Produce precision high resolution scattering maps using broadband nearfield sparse array technology

- Identify classes of scattering by acoustic color

- Simultaneously measure bottom characteristics using broadband probe-pulse forward scattering technology.

BOTTOM CLUTTER HYPOTHESIS TESTING



ROUGHNESS INHOMEGENEITY	TILT MODULATION	OUTCROPPING	SUB-BOTTOM INHOMOGENEITY	GAS POCKET
• $\sim k^4 S(k)$ • broadband • blue spectrum • left-right symmetry	• θ^4 slope dependence • asymmetric	red-blue-red spatial color pattern	red spectrum related to depth	• narrow band • low frequency • shadow zone

WASPS

Areté's Wideband Acoustic Scattering Processor System

Incorporates advanced processing and imaging technology into a unique and important tool for low and mid-frequency applications.

Features

- Full spectrum capability without nested arrays
- Very high resolution in 3D (range, cross-range, depth)
- Precision imaging of acoustic scene
- Acoustic color classification

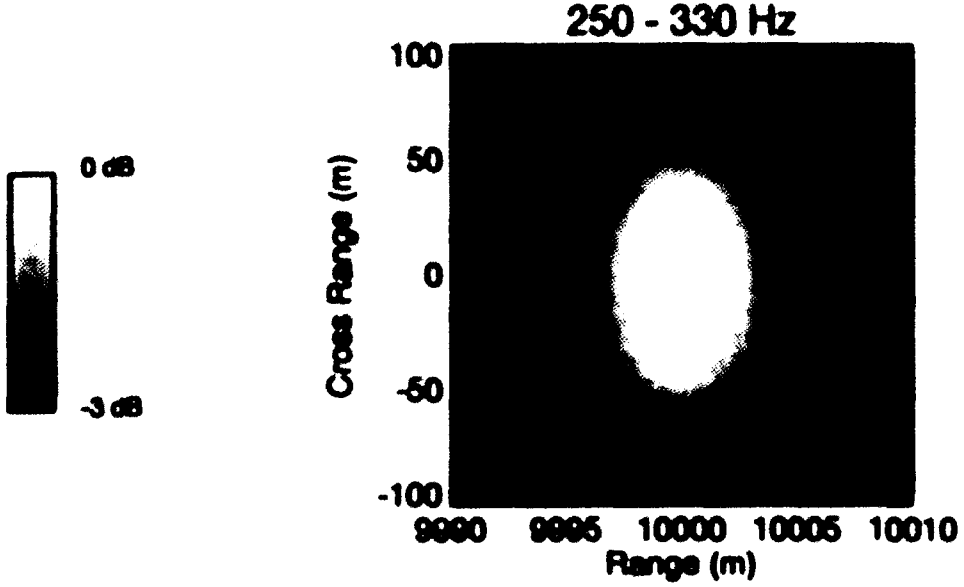
Viability

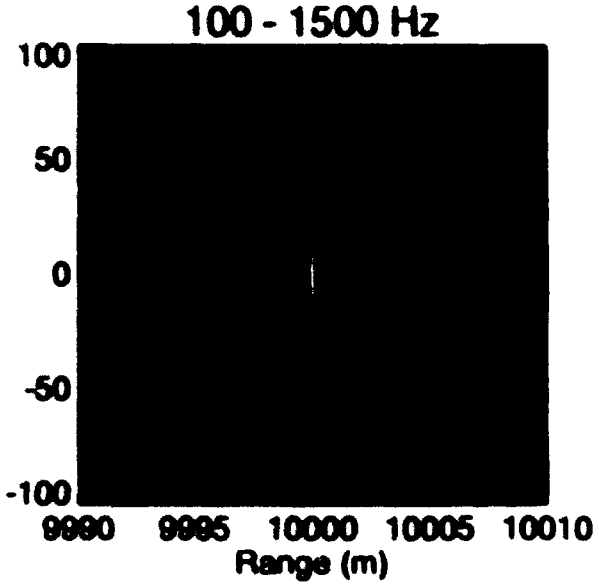
- Can exploit any array configuration
- Concepts validated on Navy and ARPA systems
- Computational requirements within capability of emerging small, low-cost multiprocessor systems.

WASPS UNIQUE TECHNOLOGY

Technique	Effect	Utility
BROADBAND BEAMFORMING (≤ 200 % BANDWIDTH)	- Maximum temporal resolution - Full spectrum coverage - Uses all signal energy	- LFA multipath estimation - Frequency Diversity - Maximal SNR for impulsive sources
SPARSE ARRAYS	- Significantly increase angular resolution - Not restricted to λ/2 sensor spacing	- Classification based on 2D structure - Conventional arrays can be used - Increased AG for nested configuration
NEAR FIELD FOCUSING	- Full array gain and resolution at any range	- Use in short range (5-10 nmi) shallow water applications - Acoustic microscope (< 1 nmi)
EXPLOSIVE WAVEFORM DECONVOLUTION	- Increases temporal resolution to the inverse bandwidth	- LFA multipath classification with explosives
ARRAY AUTO-COHERING	- Localizes array position	- Full gain without elaborate measurement systems - Left-right resolution
HIGH RESOLUTION IMAGING	- Natural presentation of acoustic scene	- Rapid operator assimilation of data
SPECTRAL COLOR SEGMENTATION	- Presents relative frequency content of scatterers	- Target and environmental classification
INCOHERENT DEPTH ESTIMATION	- Determine contact depth	- Classification and localization without matched field replica
MULTIPROCESSOR ARCHITECTURE AND HARDWARE	- Near real time throughput	- Small, low cost processor systems

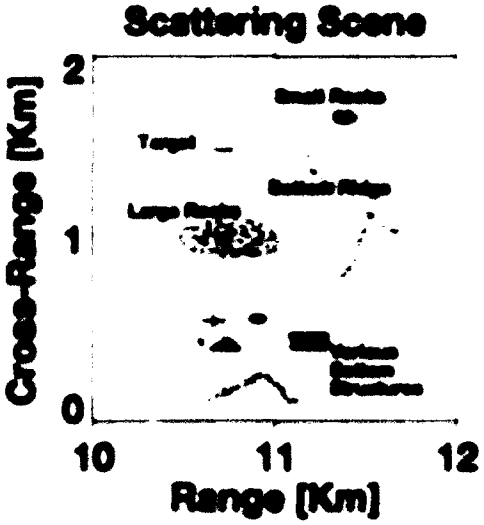
Theoretical 3 dB Resolution Cell: CST MFA

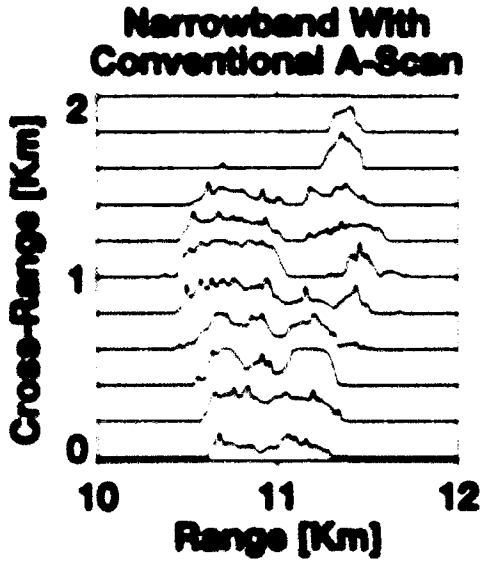


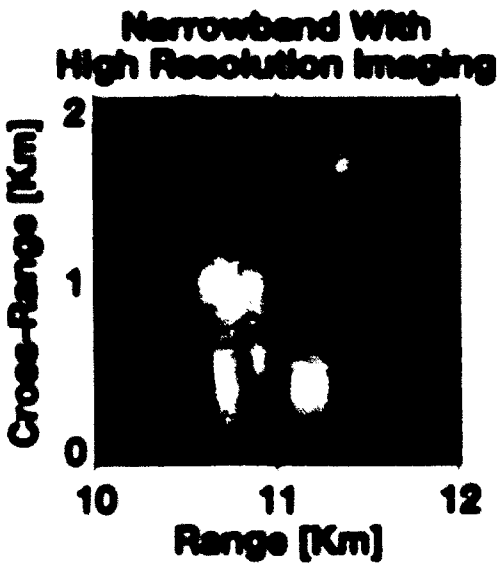


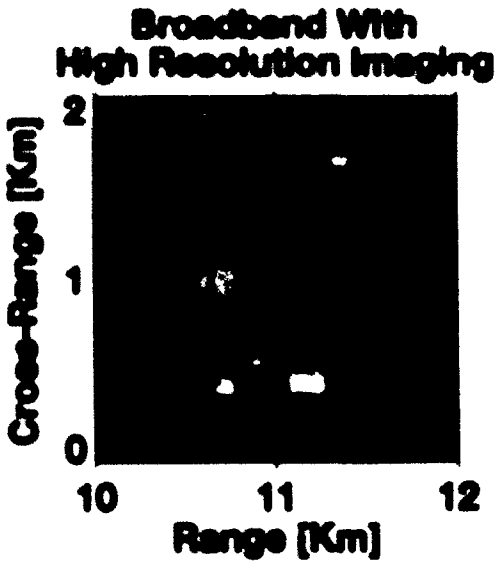
Beampattern:	$\lvert b(\theta,\omega)\rvert^2$	$\left\lvert \int b(\theta,\omega)e^{\omega t}d\omega \right\rvert^2$
Angular Resolution:	$\frac{\lambda}{L} = 0.93$ deg.	$\sqrt{2}\frac{c}{L\Delta\omega} = 0.27$ deg.
Sidelobe:	$\frac{1}{N^2} = -42$ dB	$\frac{1}{N^2} = -42$ dB

Simulated Results For The CST MFA Receiver

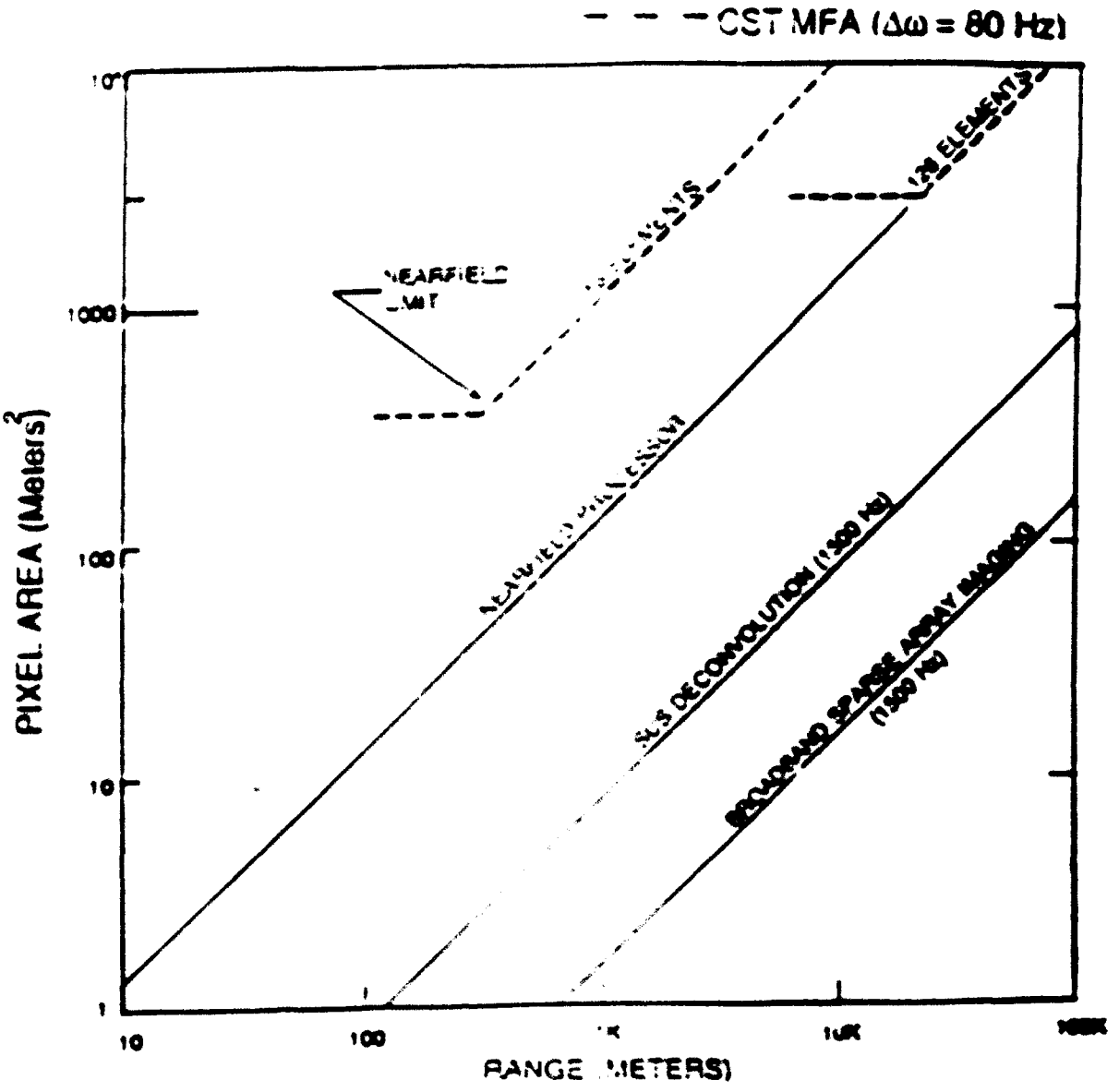




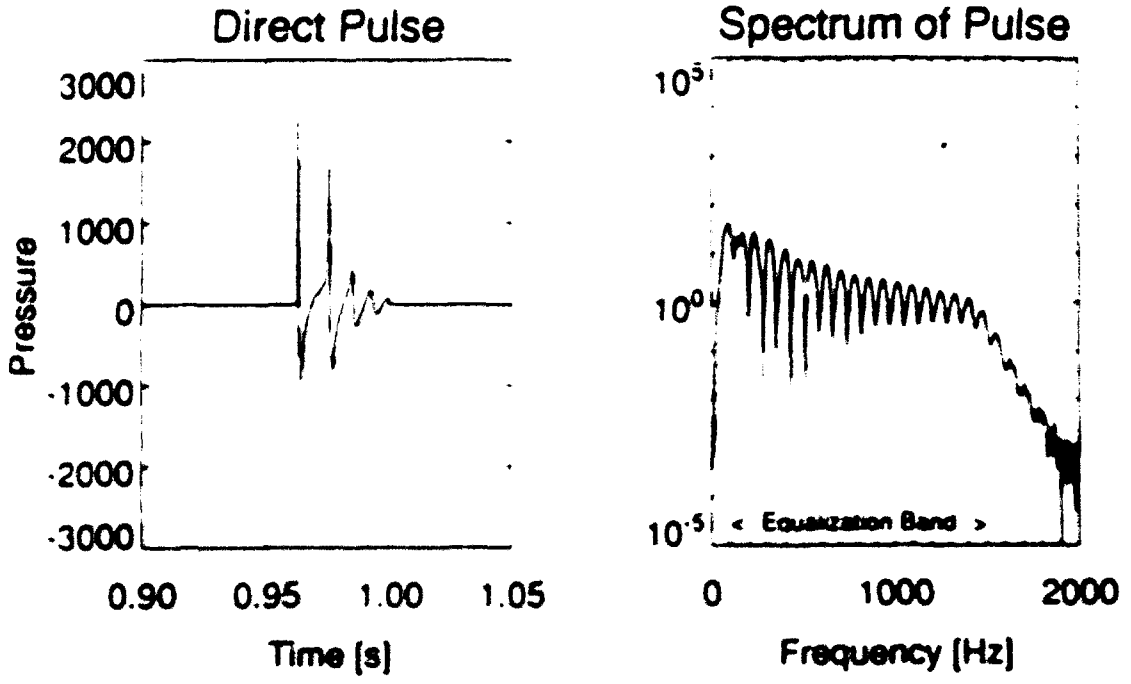


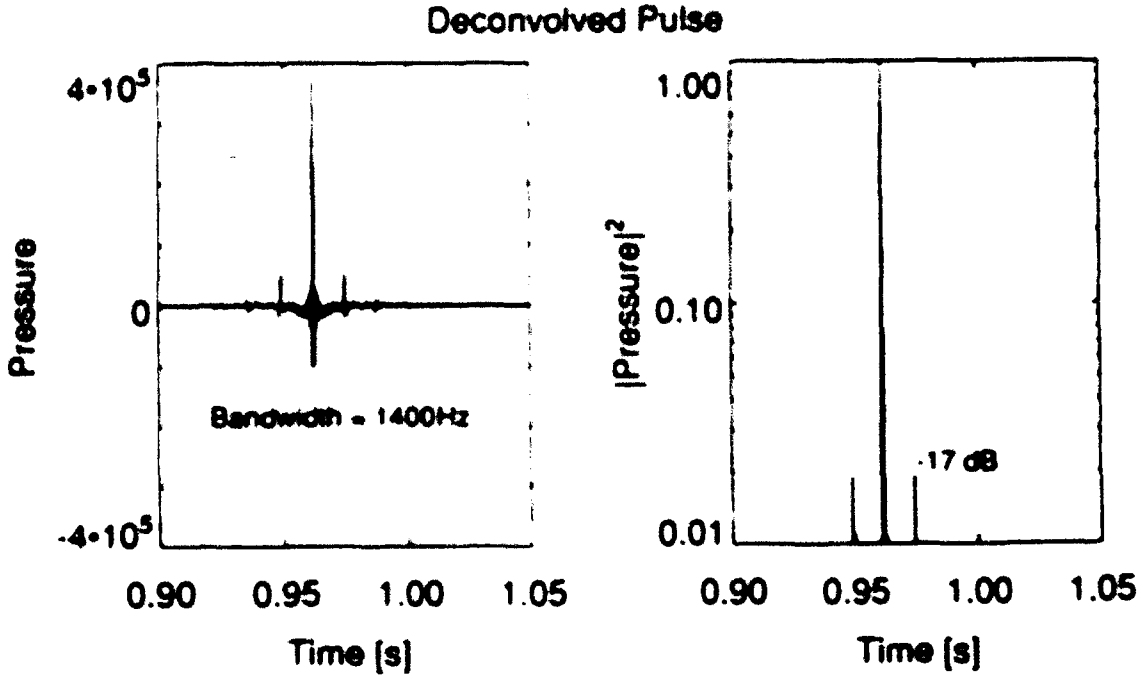


THEORETICAL EFFECTS OF PROCESSING TECHNIQUES ON SPATIAL RESOLUTION OF CLUTTER



SUS Deconvolution





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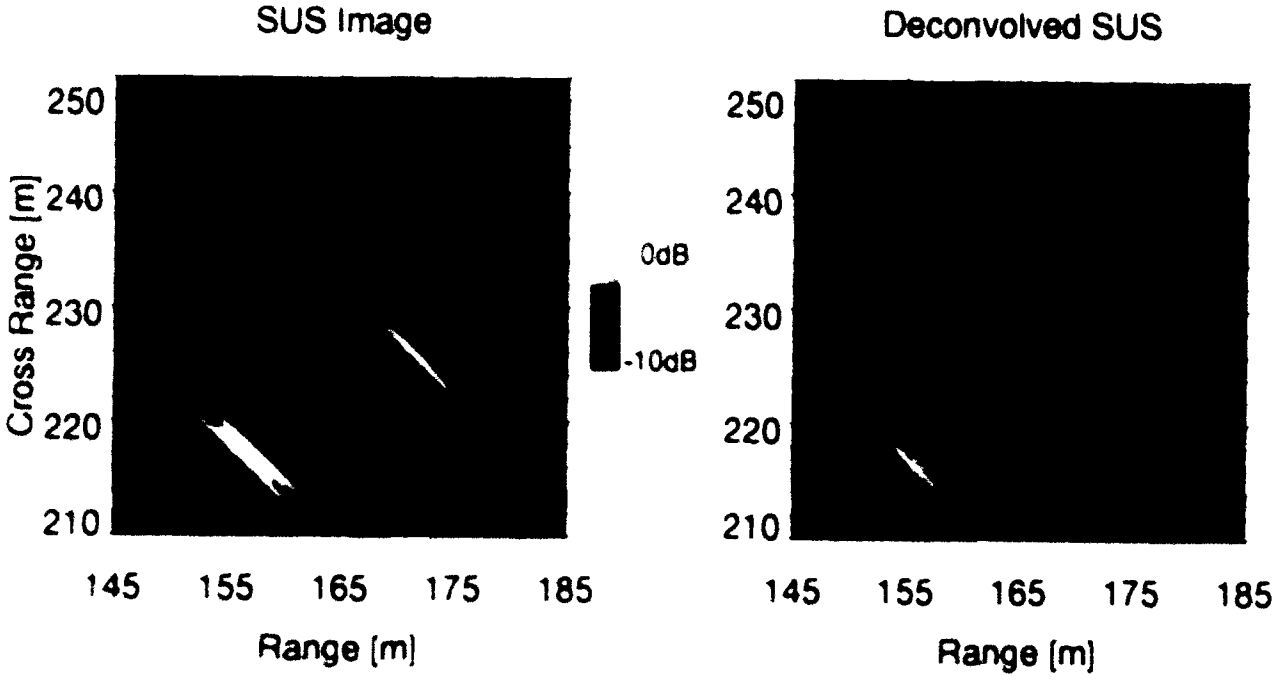
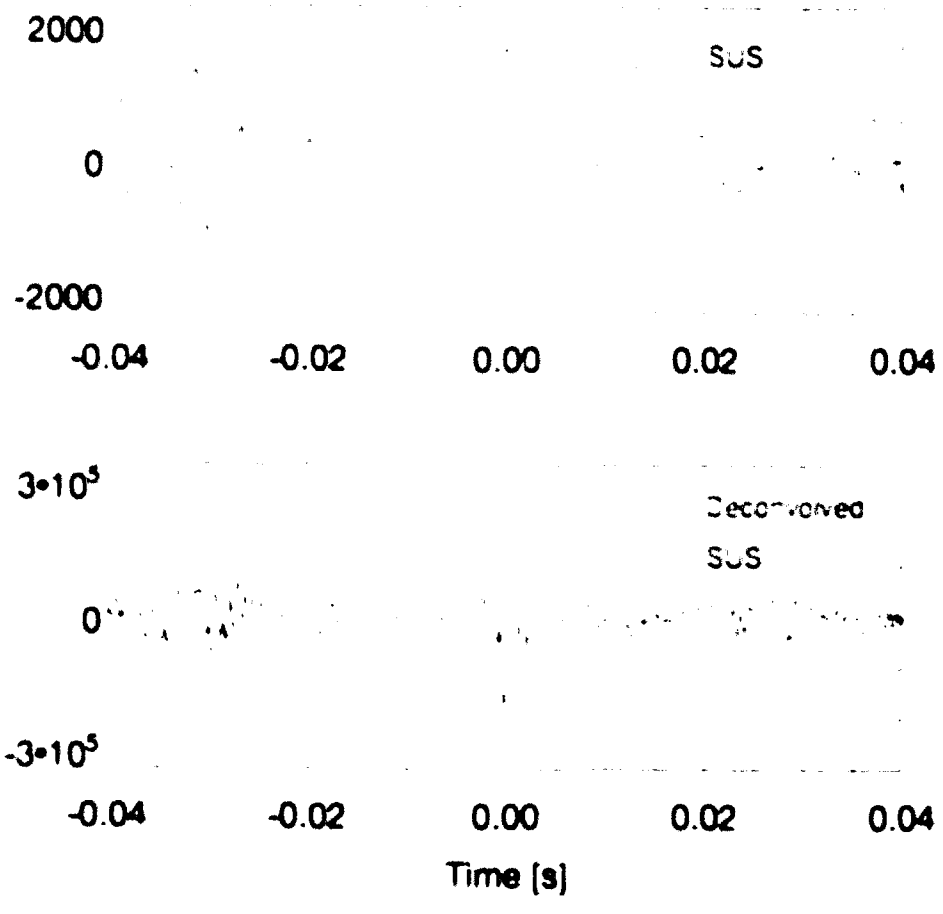
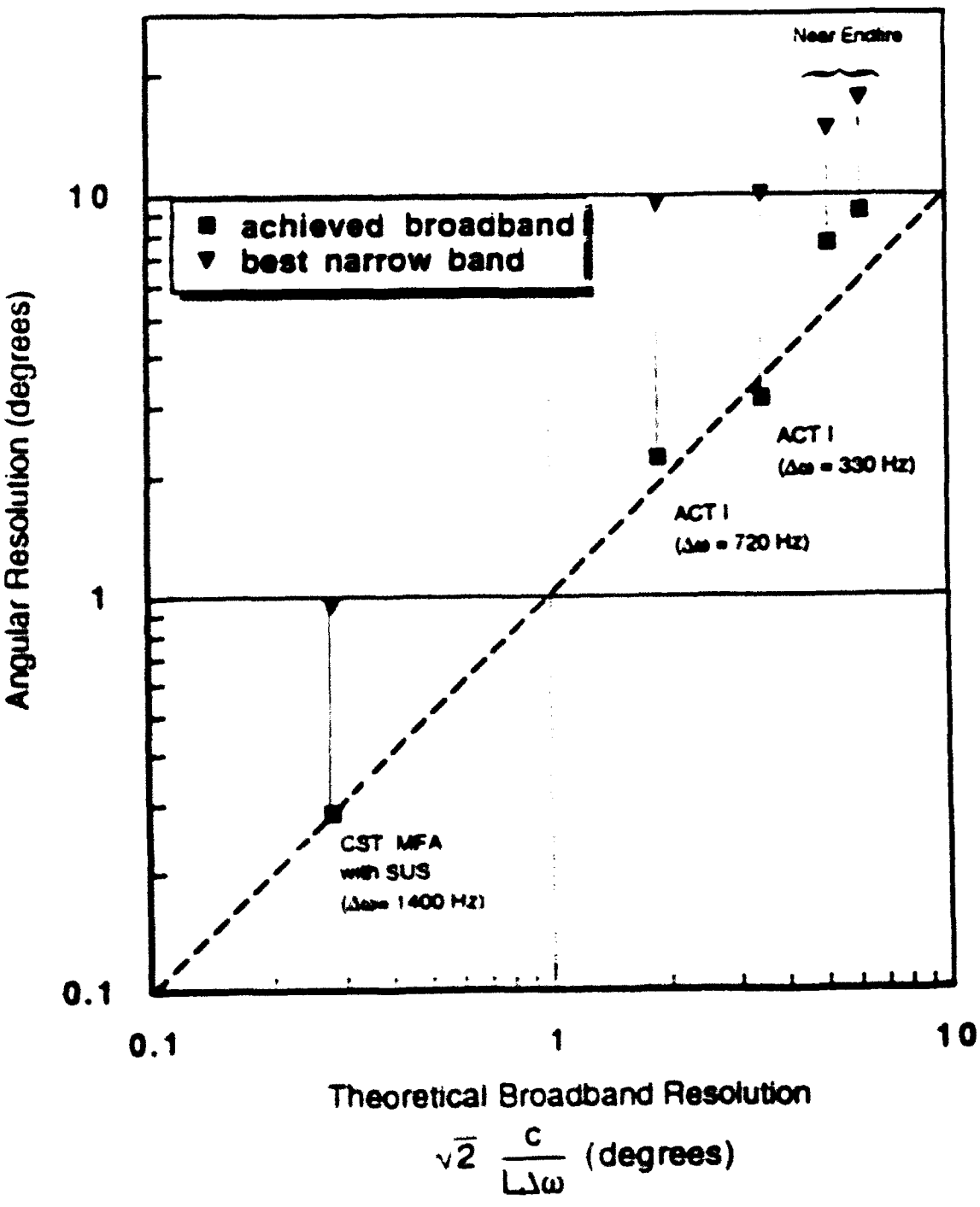
Effect of SUS Deconvolution





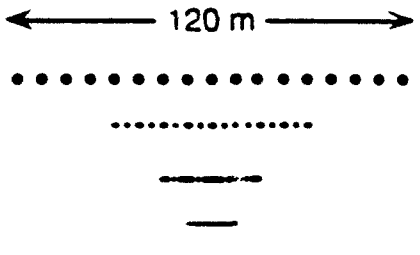
COMPARISON OF ACHIEVED VS THEORETICAL ANGULAR RESOLUTION (U)



BROADBAND SPARSE ARRAY ECONOMY

Bandwidth : 100 - 1600 Hz
DI : 12 dB

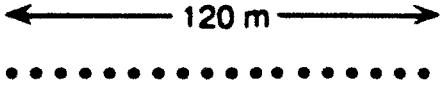
Classical Nested Octave Design



Band	Sensor Spacing
100 - 200 Hz	Δx = 7.5 m
200 - 400 Hz	Δx = 3.8 m
400 - 800 Hz	Δx = 1.9 m
800 -1600 Hz	Δx = .9 m

Number of Sensors: 41

Broadband Sparse Array Design



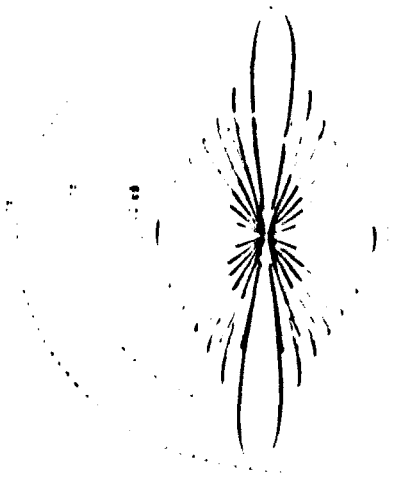
Band	Sensor Spacing
100 -1600 Hz	Δx = 7.5 m

Number of Sensors : 17

COMPARISON OF NARROWBAND AND BROADBAND BEAMPATTERNS

13 Element Array Cut @ 100 Hz

CW @ 100 Hz

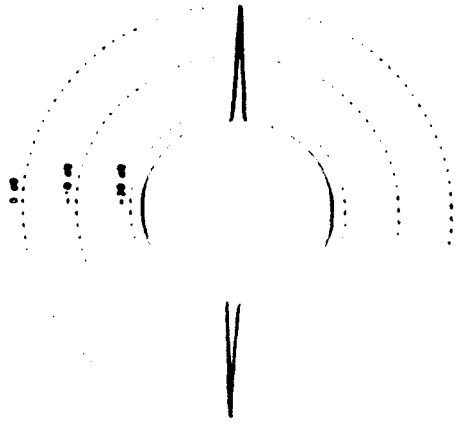


(a)

CW @ 300 Hz

(b)

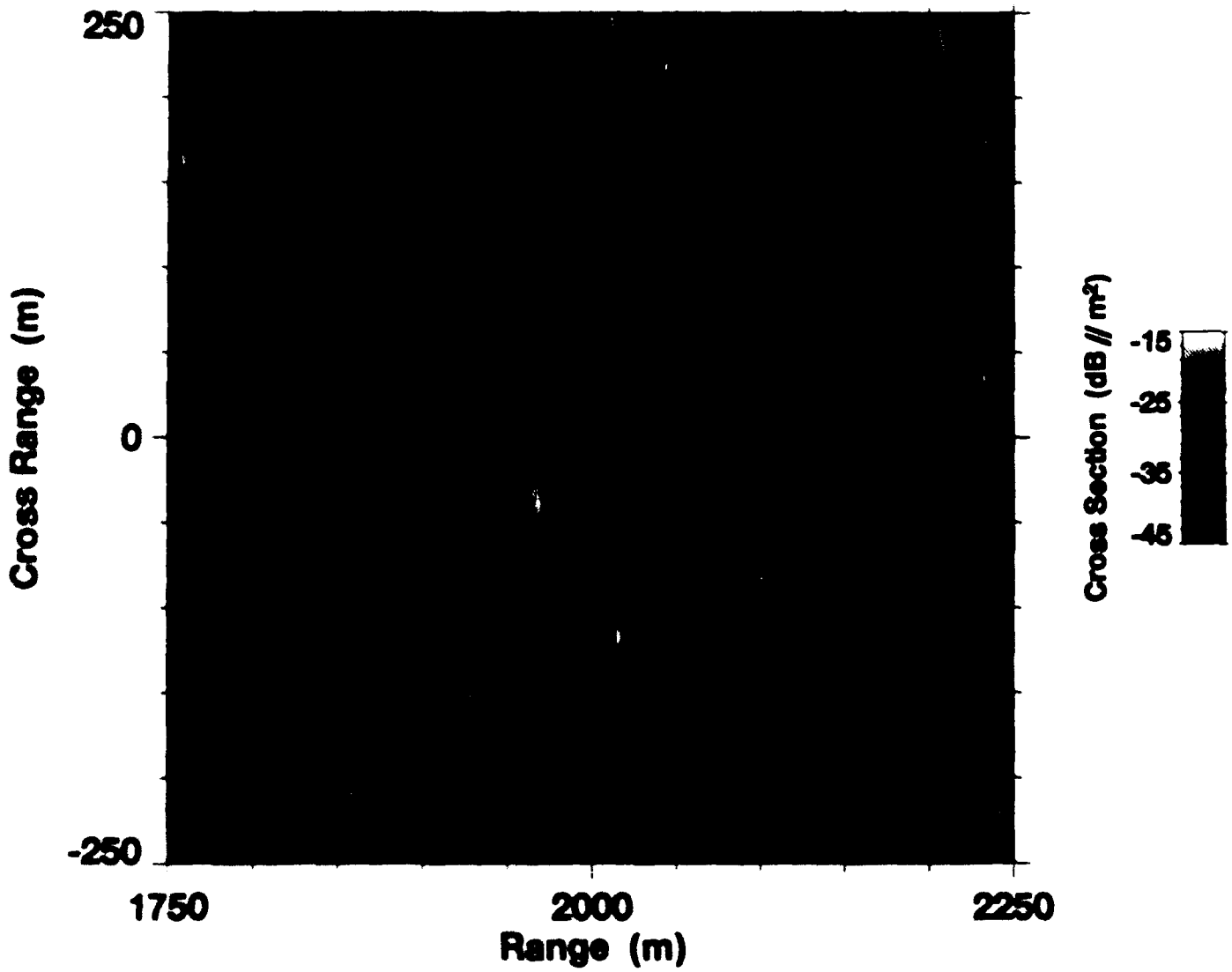
100 - 1500 Hz @ t = 0



(c)

	(a)	(b)	(c)
3 dB Beamwidth	9.5 deg	Ambiguous	1.4 deg
Sidelobe Level	-22 dB	-22 dB	-22 dB

CST7 Surface Reverberation
14 m/s Wind, Sea State 5



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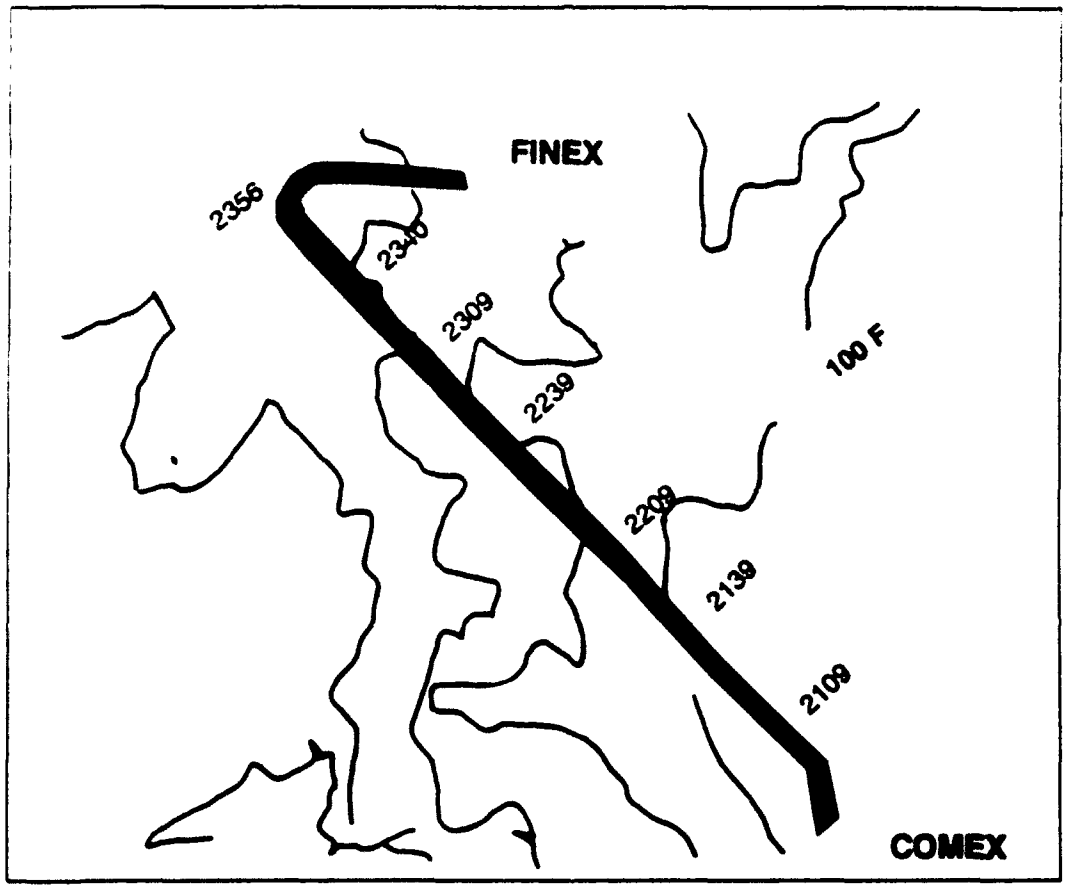
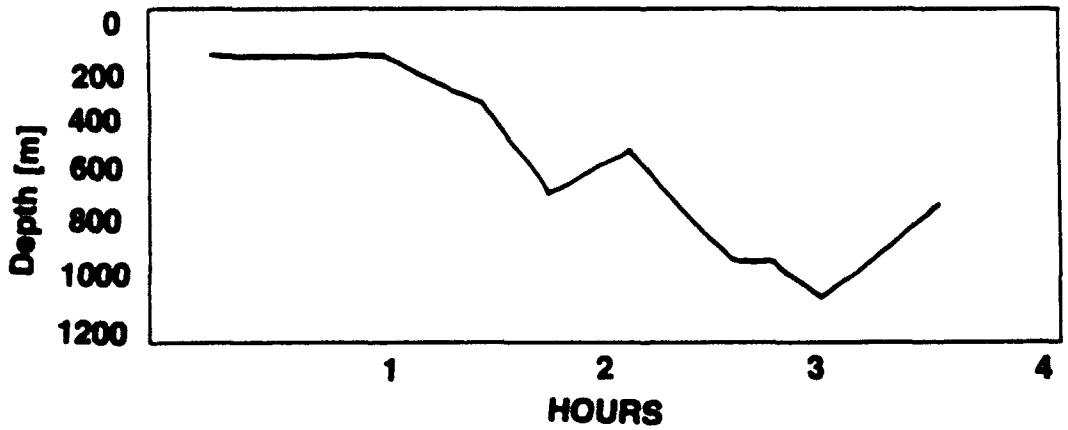
CST-7 PHASE 3 RUN 21A

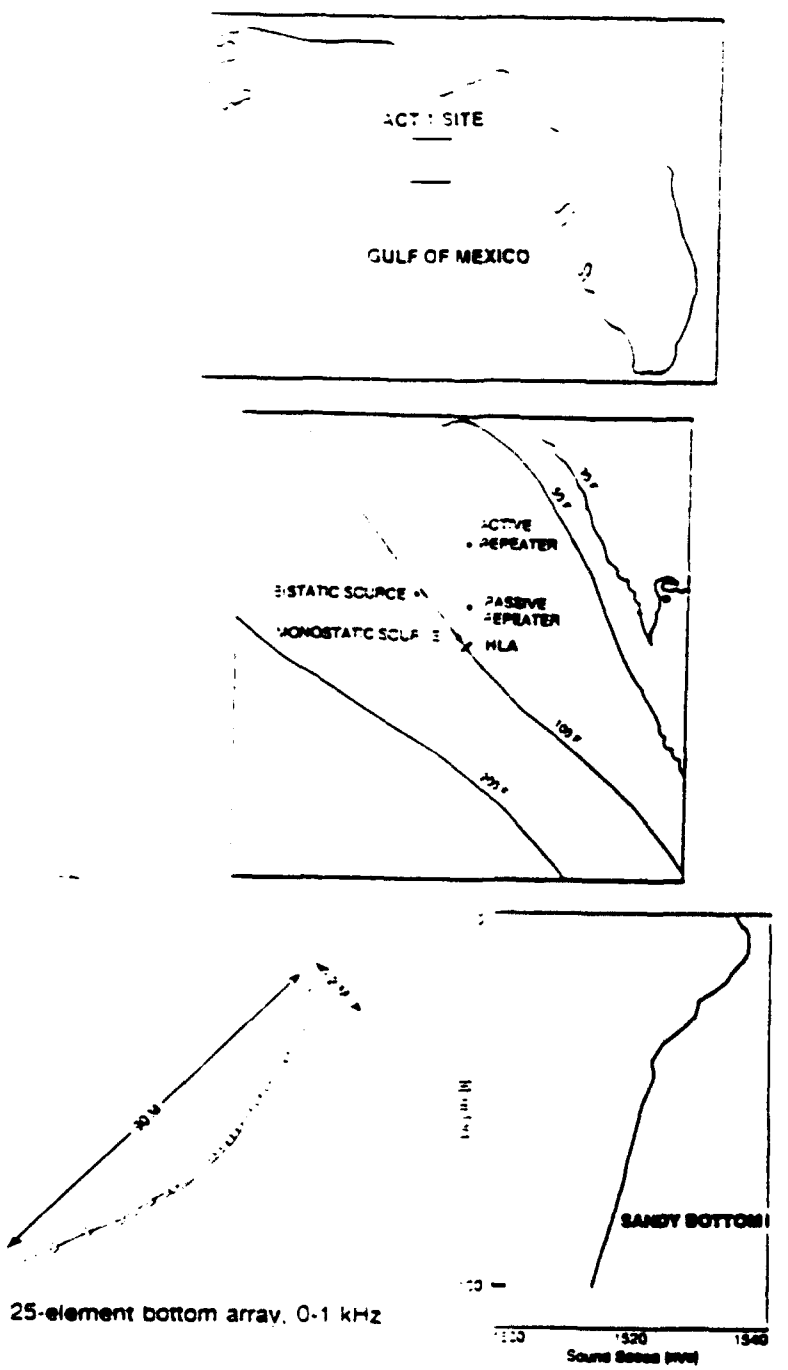
RUN TRACK



DEPTH TRACK

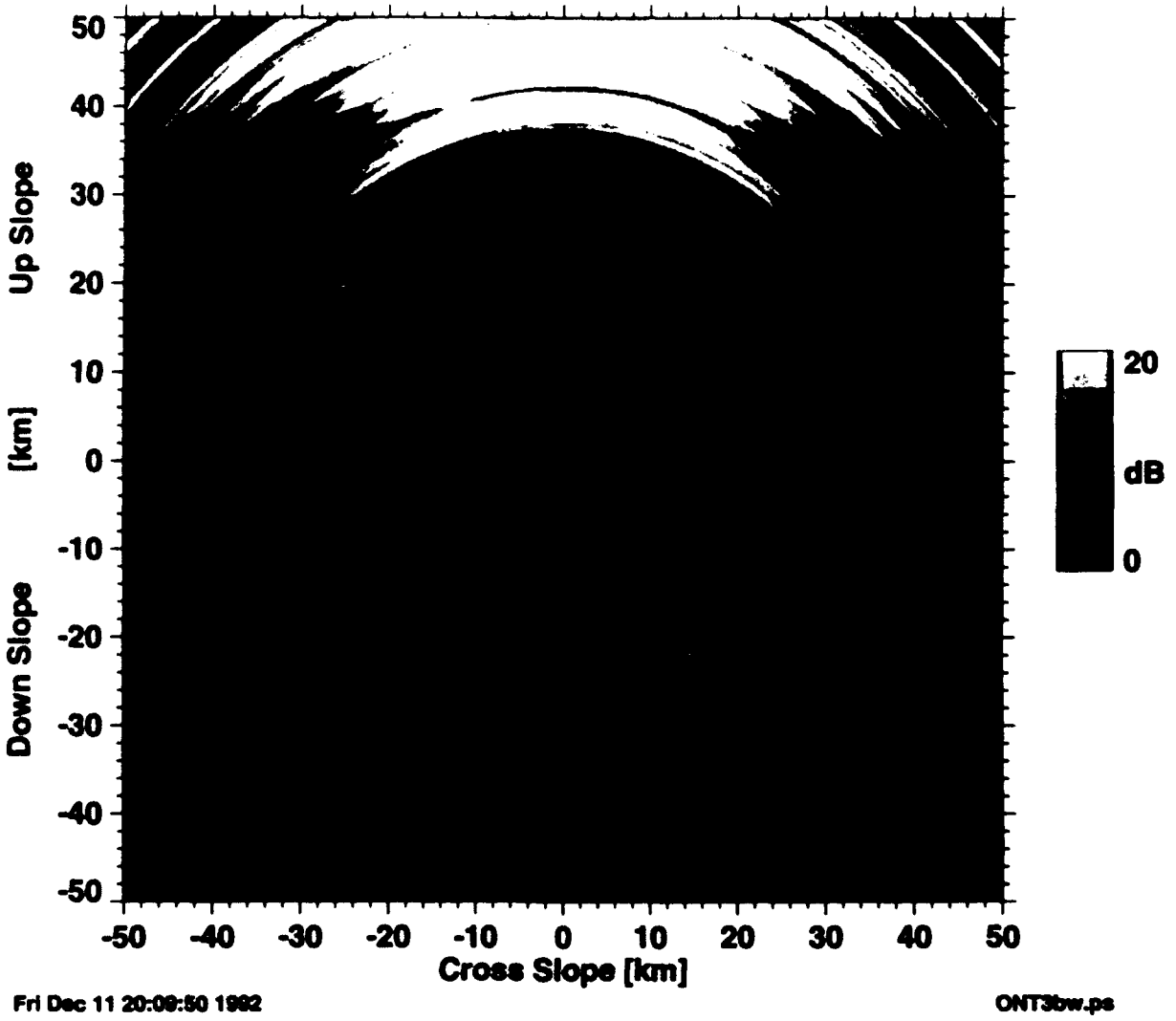


DARPA ACT 1 CONFIGURATION

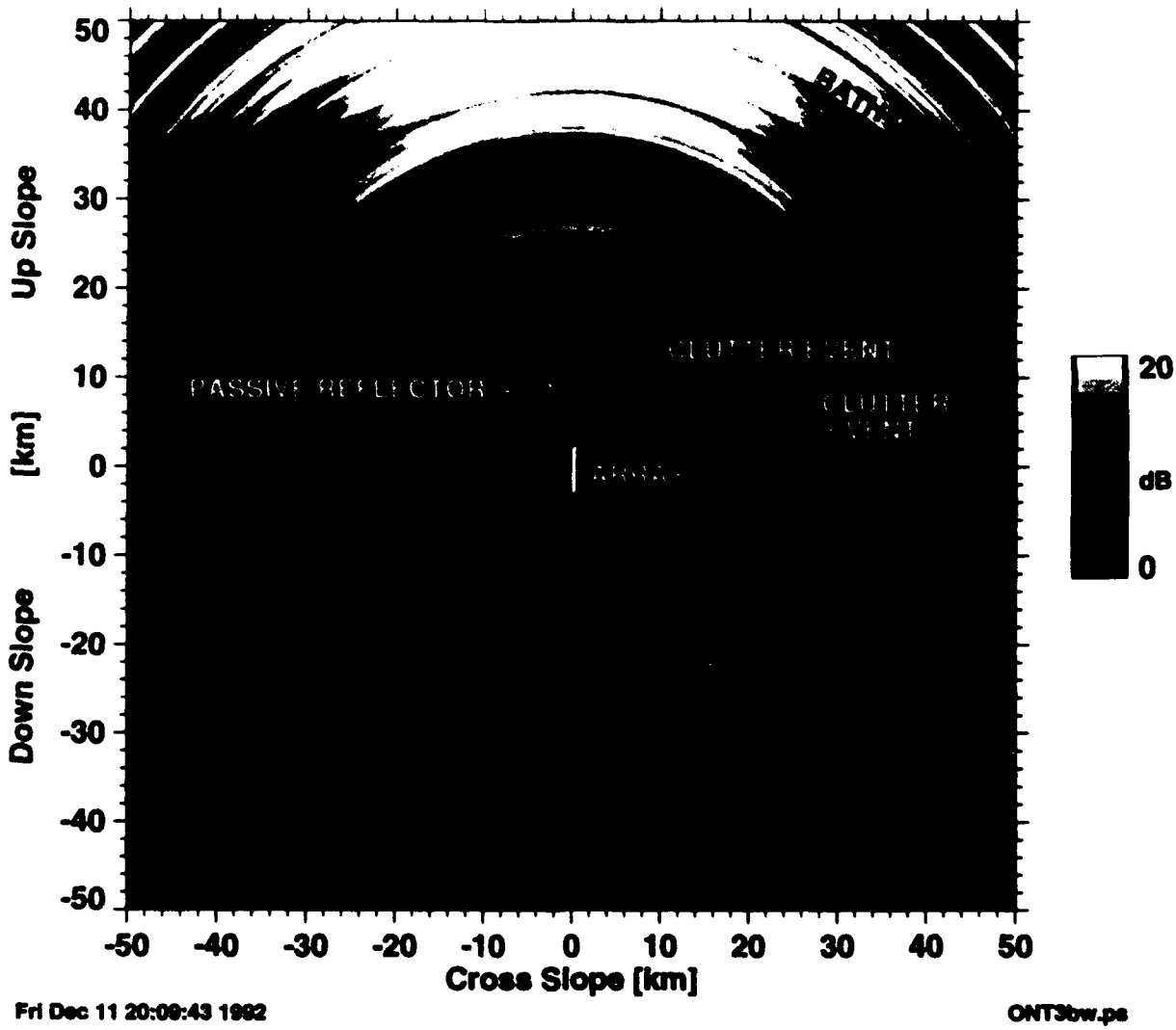


25-element bottom array, 0-1 kHz

DARPA ACT1 TEST
WIDEBAND SCATTERING
30-400HZ

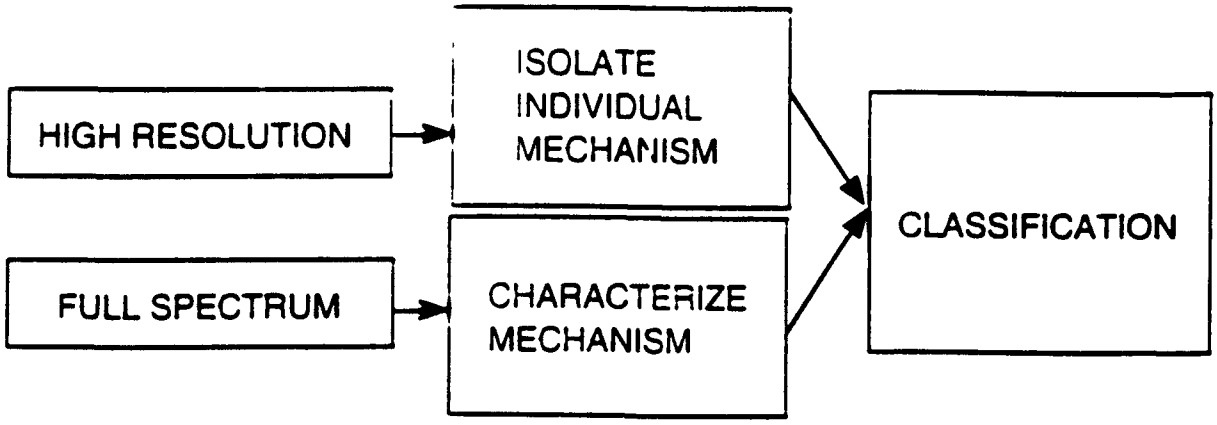


DARPA ACT1 TEST
WIDEBAND SCATTERING
30-400HZ



FULL SPECTRUM FOR CLASSIFICATION

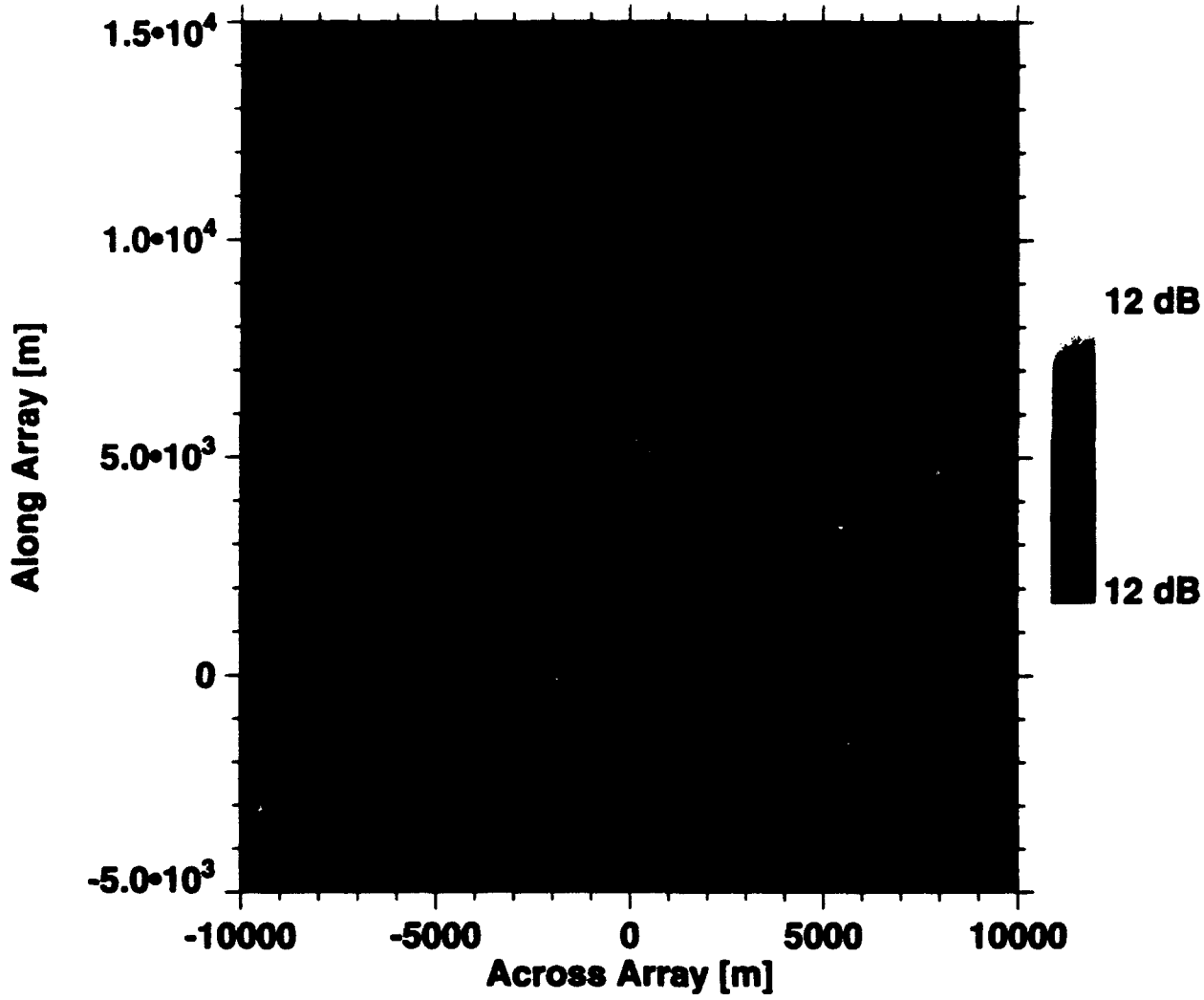
Potential contacts should have distinguishing spectral characteristics



Scattering Process	Characteristic
sub-bottom features	low frequency
bottom interface	reflects bottom correlation scale
biologics	Rayleigh scattering and swim bladder resonance
near-surface bubbles	reflects plume details
data glitches	"white noise"
targets	reflects complex elastic structure

TWO-SIDED BROADBAND IMAGING

UNDOA on Left, False Alarm on Right



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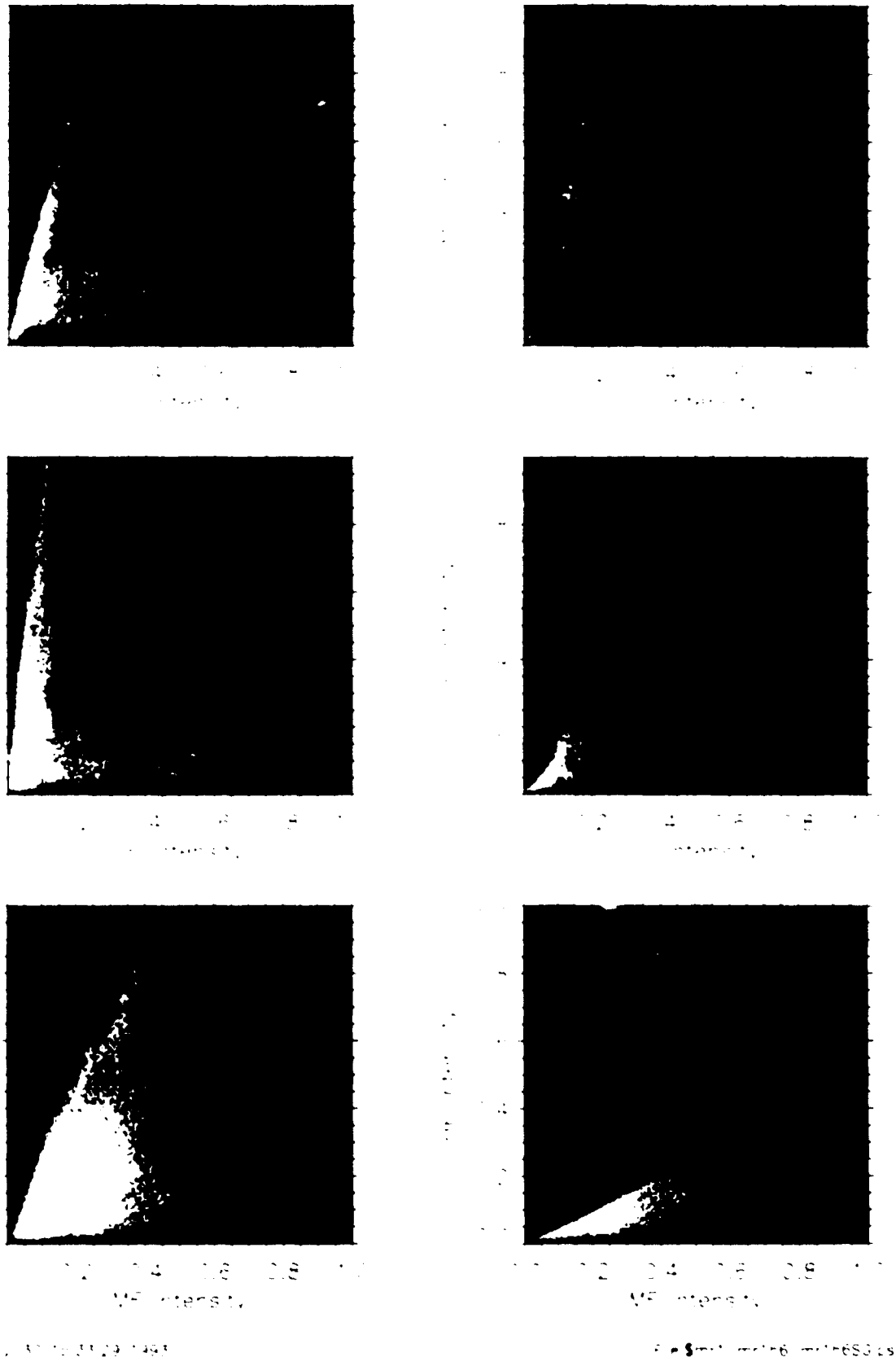
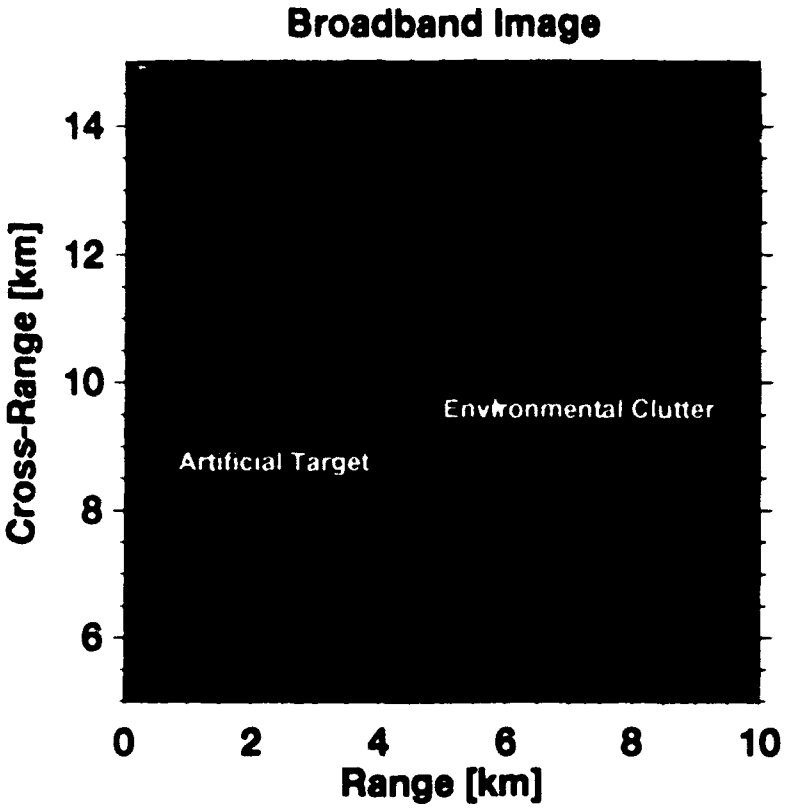
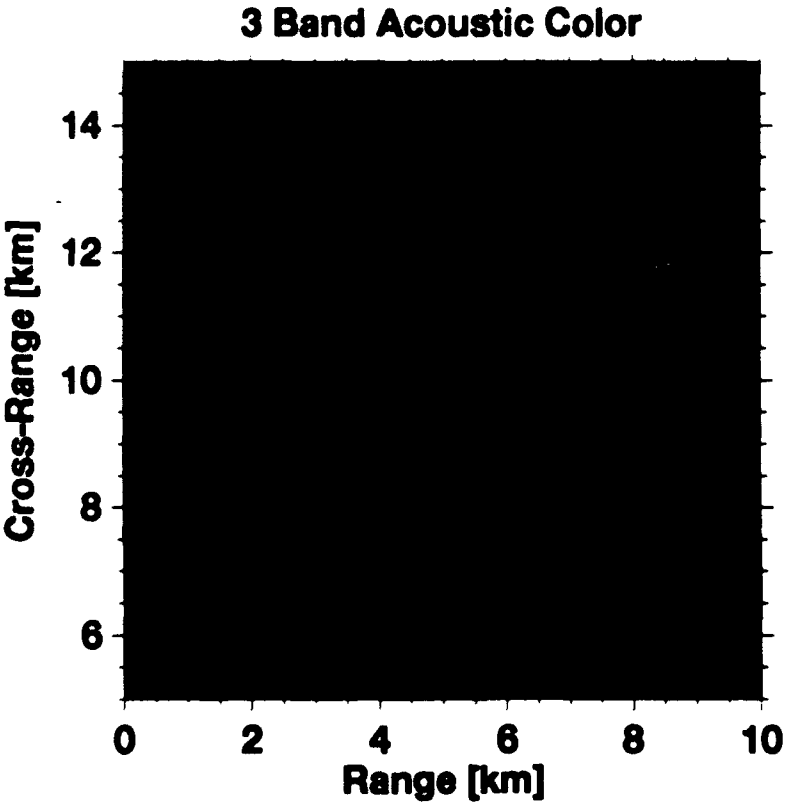
Shot: mr1h6







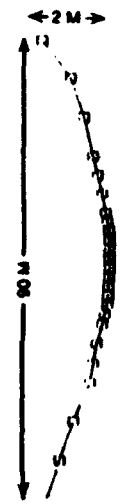
plot2.ps

Figure 4 Two scattering events with similar spatial structure which can be classified using their spectral content. Data from ARPAs ACT I Gulf of Mexico Test.

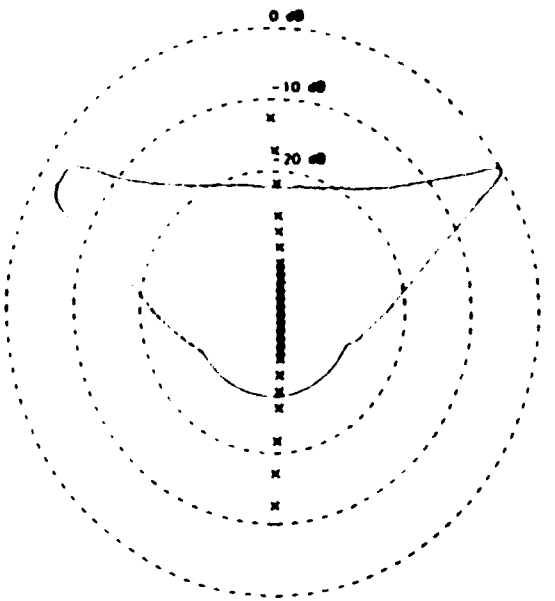
EXAMPLE OF LEFT-RIGHT AMBIGUITY RESOLUTION WITH WASPS

Active: 100 - 400 Hz

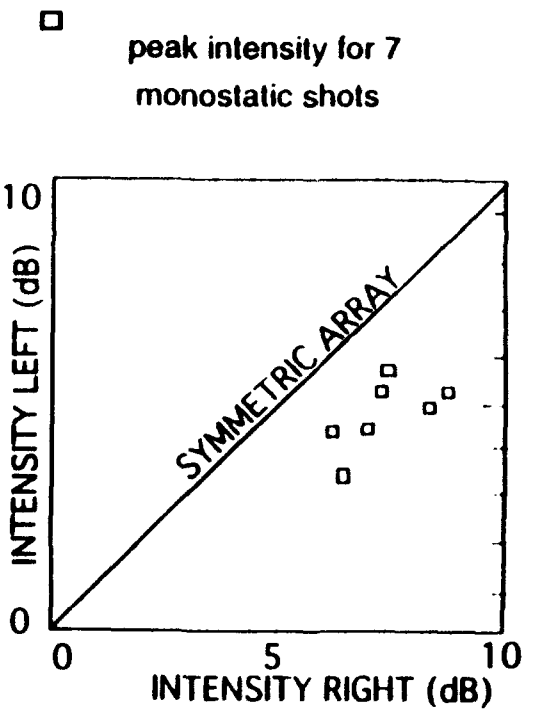
Array Asymmetry



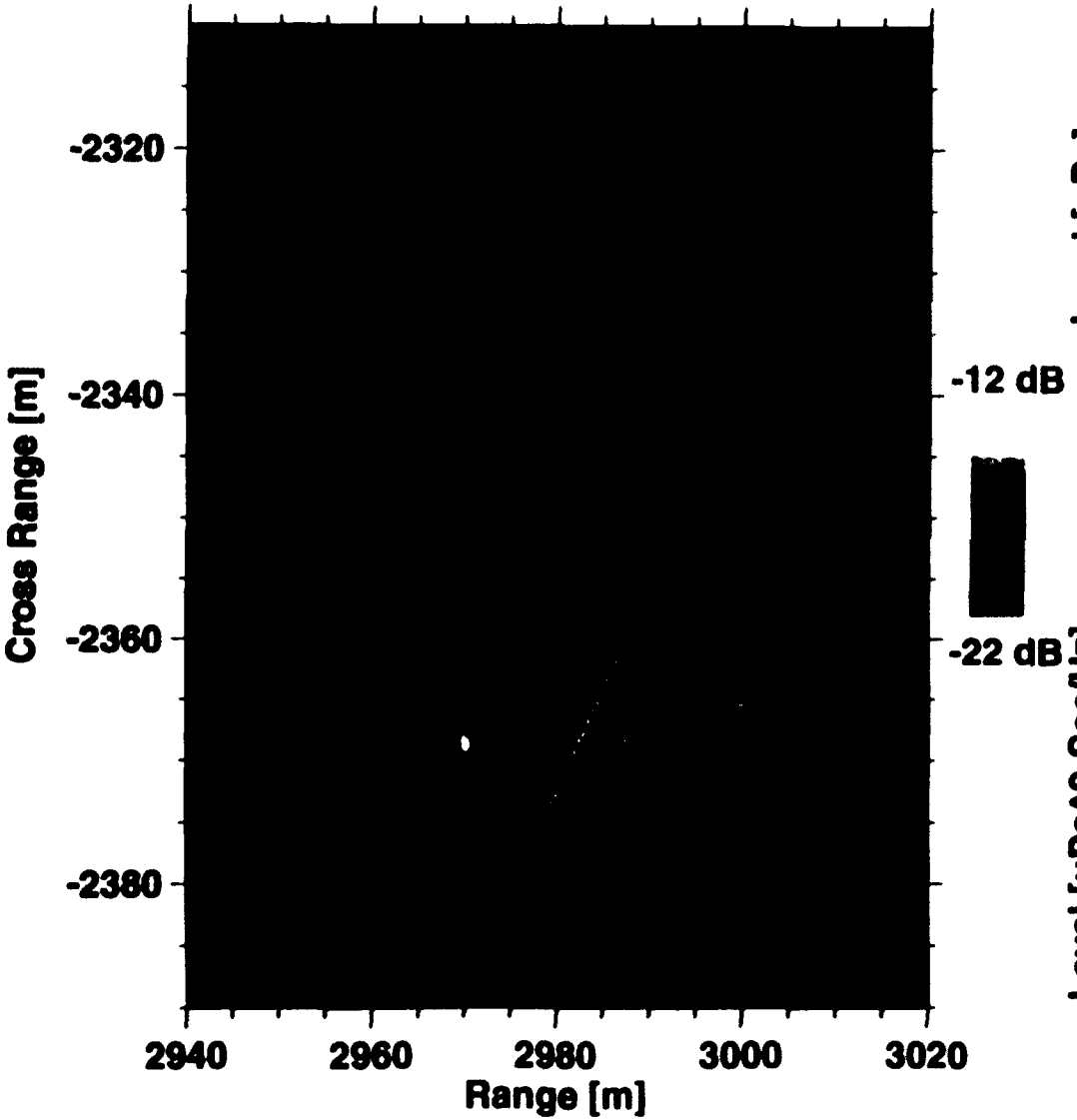
Two-Sided Beampattern

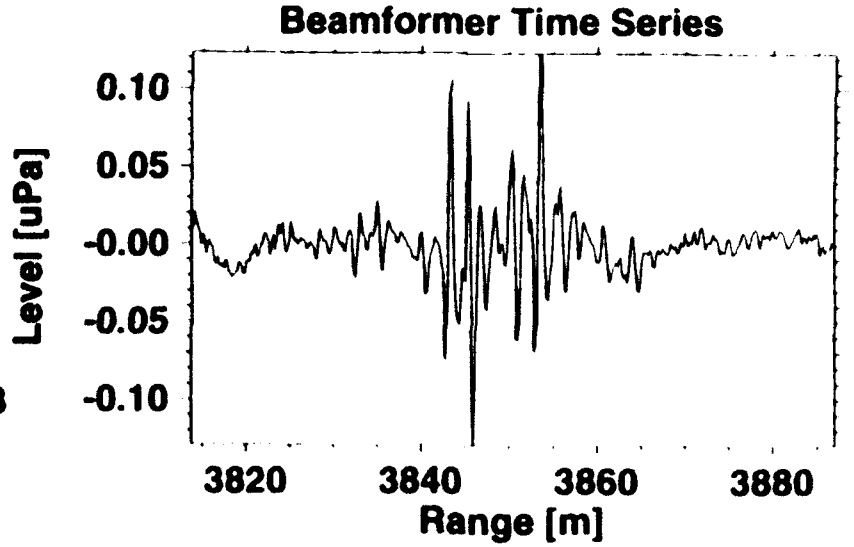


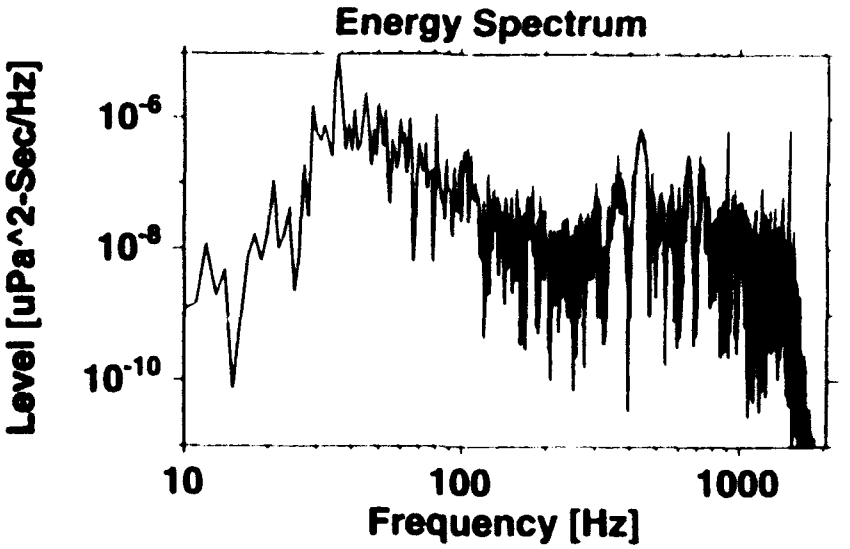
Left-Right Resolution of Clutter Event at 26 km



Volume Feature and Associated Multipaths From CST7

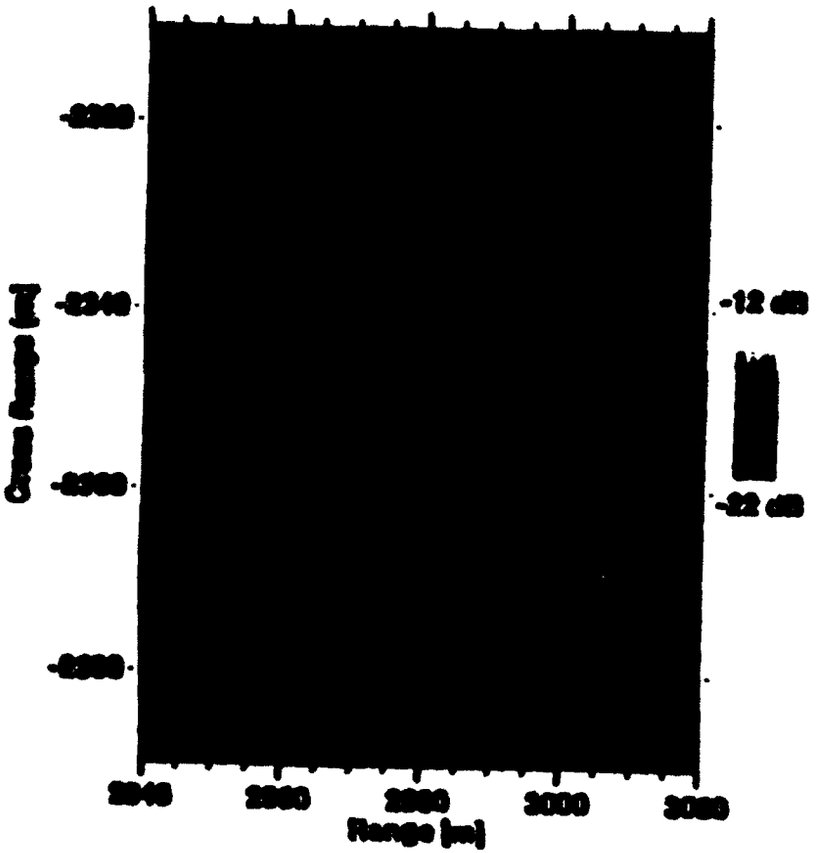




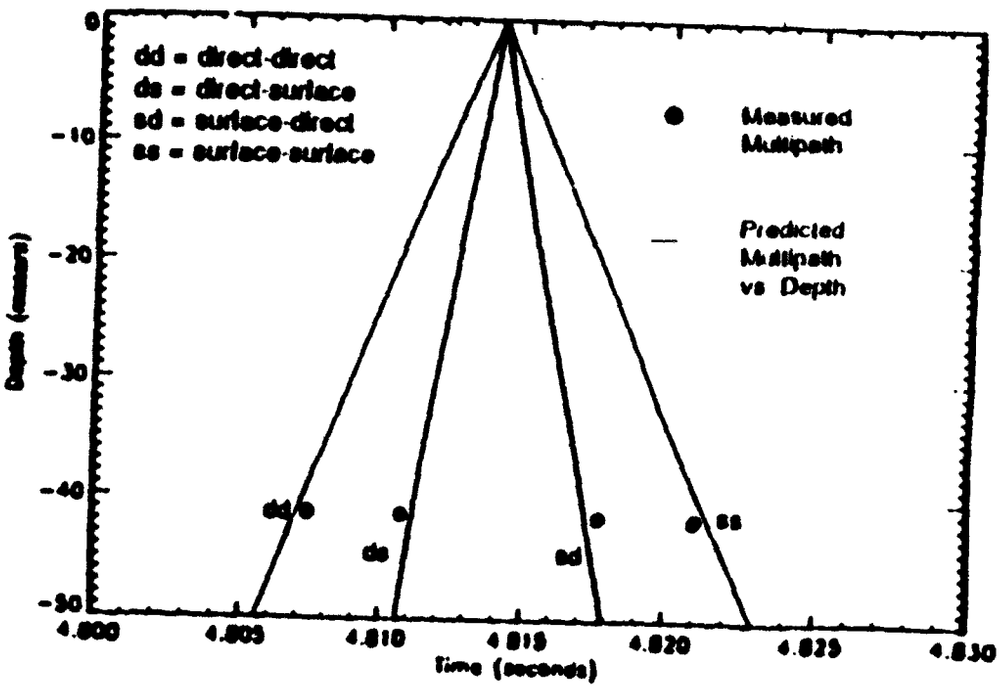


EXAMPLE OF DEPTH CLASSIFICATION BROADBAND LFA

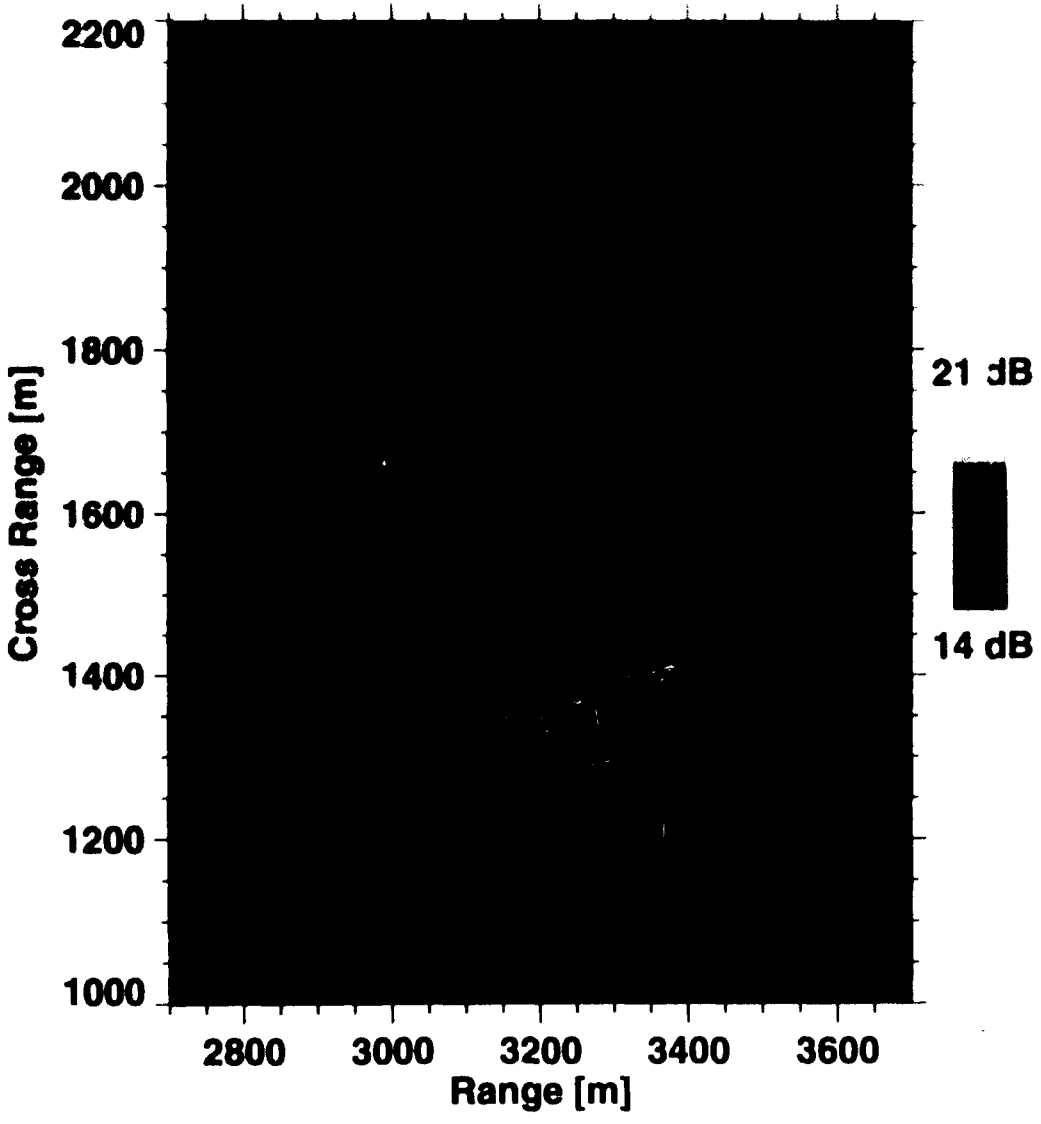
MULTIPATH RESPONSE

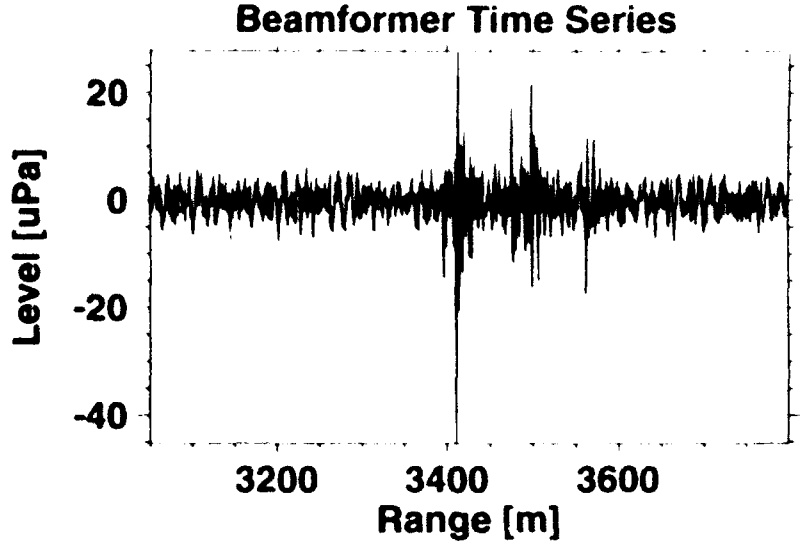


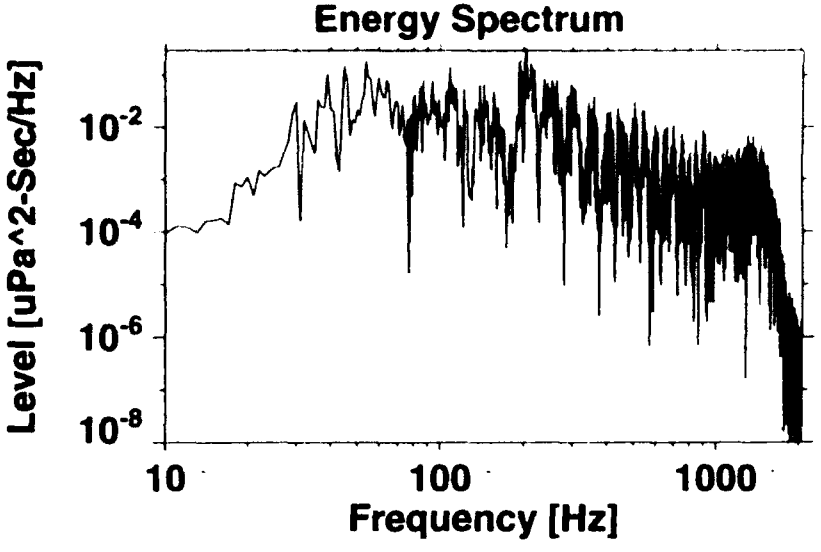
DEPTH LOCALIZATION



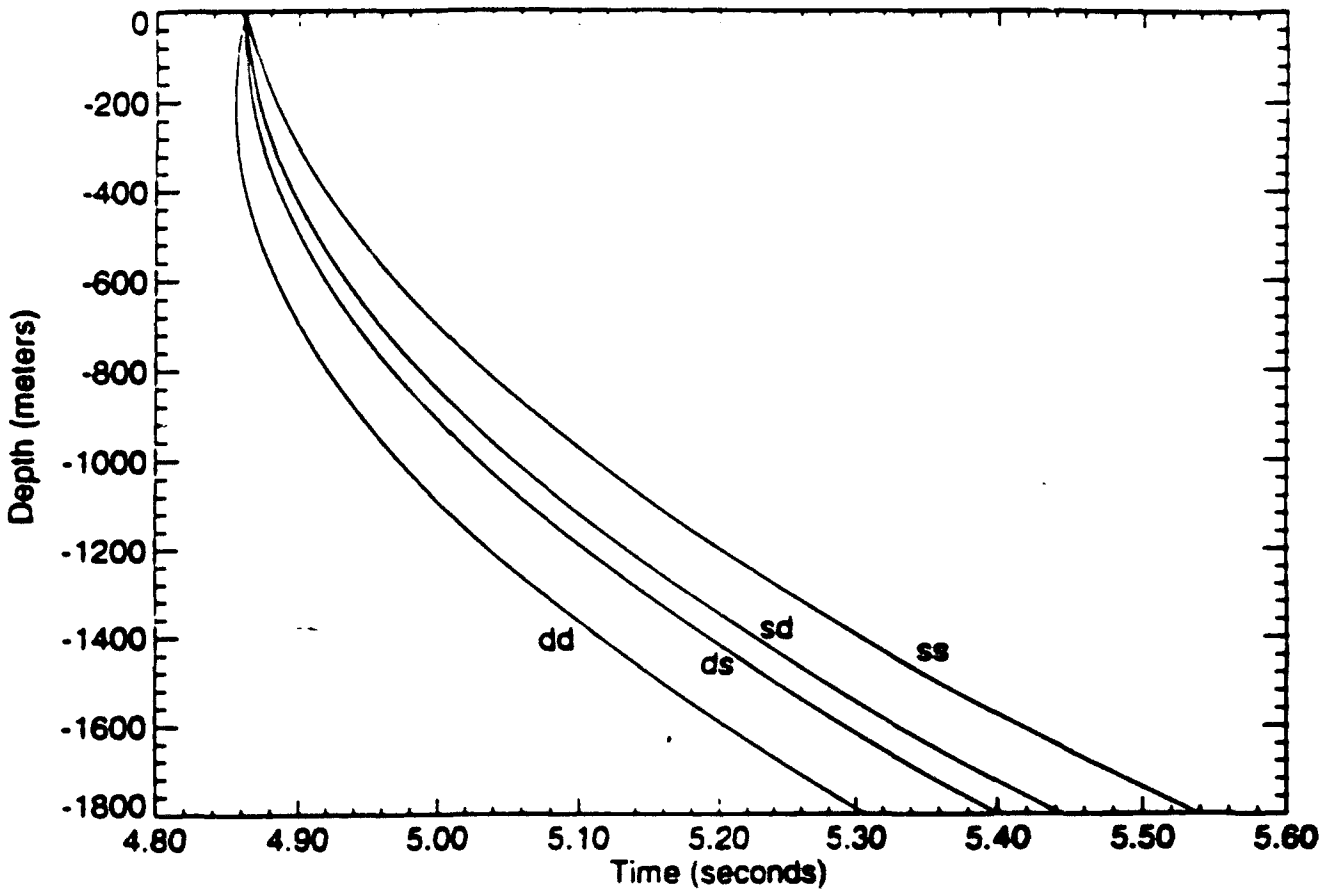
Bottom Feature and Associated Multipaths From CST5



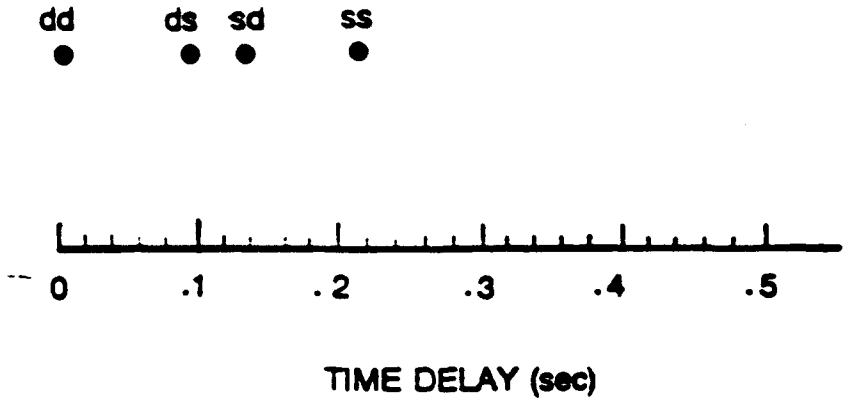




PREDICTED MULTIPATH FOR A CONTACT AT (3050m, 1450m), CST 5



MEASURED MULTIPATH FOR A CONTACT AT (3050m, 1450m), CST 5



CURRENT AND PENDING ARETÉ DATA BASES

Current Data Base

Experiment	Sponsor	Location	Water Depths (m)	Frequencies (Hz)	Comments	Sensor
CST-5	ONR/AEAS	Mediterranean Sea	1000-2000	100-1500	Bottom Features	Horizontal towed array
CST-7	ONR/AEAS	Gulf of Alaska	5000	100-1500	Suface and volume features	Horizontal towed array
CST-7	DARPA	Washington Coast	150-500	100-1500	Bottom Features	Horizontal towed array
Broadband Transmission	Martin Marietta	Santa Cruz Range	300-800	500-5500	Bottom and surface reflection	Vertical array
Dolphin Target	ONR, Martin Marietta	San Diego Coast	100-3800	100-6000	Bottom loss, backscattering and features	vertical array
ACT-1	DARPA	Gulf of Mexico	50-400	50-2000	Long-range bottom interaction	Bottom horizontal and vertical arrays

Pending Data Base

Experiment	Sponsor	Location	Water Depths (m)	Frequencies (Hz)	Comments	Sensor
CST-7	DARPA	Washington Coast	150-2000	100-1500		SQR-19 towed array